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Alexander B. Lekov
J. Douglas Balcomb

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PASSIVE SOLAR SYSTEMS PERFORMANCE UNDER CONDITIONS IN BULGARIA

Alexander B. Lekov* and J. Douglas Balcomb
Solar Energy Research Institute
Golden, Colorado 80401
U.S.A.

ABSTRACT

This paper presents energy performance of 12 passive solar systems for three climatically different zones of Bulgaria. The results are compared with a base-case residential house that has a design typical for these areas. The different passive solar systems are compared on the basis of the percentage of solar savings and the yield, which is the annual net benefit of adding the passive solar system. The analyses are provided based on monthly meteorological data, and the method used for calculations is the Solar Load Ratio. Recommendations for Bulgarian conditions are given.

KEYWORDS

Passive solar; guidelines; buildings; energy efficiency; conservation; design tool.

INTRODUCTION

The energy performance resulting from various passive solar designs varies significantly and depends on the climate, the specific system design, the way the house is built, and how the system operates (Balcomb, 1986). Although energy performance of passive solar systems is not the only consideration for the designers, it is useful to apply this characteristic as a criterion for comparing systems and choosing the one that saves the most energy and fits other needs. This energy performance information may be applied at the early design stage before extensive detail is available on the building form and specification, or in cases when retrofit improvements are planned.

WEATHER DATA

Any attempt to use passive solar systems on buildings depends on the specific climate. It is possible to consider three climatically different zones in Bulgaria based on annual heating degree days (Bulgarian Academy of Sciences, 1981; Lekov and Balcomb, 1988). Each zone is made up of different geographic locations, generally with different levels of monthly average solar radiation. Data about solar radiation and annual heating degree days are presented in Figure 1. A map of the area is available in Lekov and Balcomb, 1988. Weather data for the cities of Michurin, Plovdiv, and Pleven are used to represent each climatic zone.

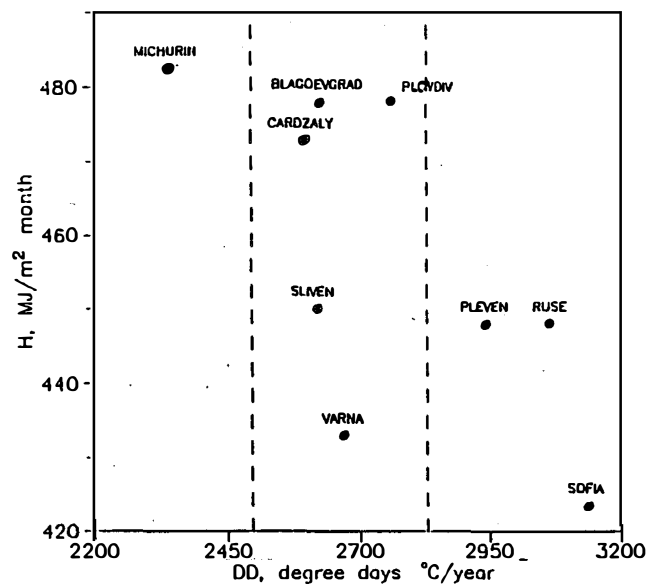

Figure 1. Data on solar radiation and annual heating degree days, three regions in Bulgaria.

ASSUMPTIONS

Performance estimates were referenced to a base-case residential house that has a design typical for these areas, which is generally two floors over a basement. The following assumptions were considered:

Living area	-	120 m²
Orientation	-	S
Floor height	-	2.8 m
Volume	-	336 m³
Windows, east	-	4.8 m²
Windows, west	-	2.4 m²
Windows, north	-	4.8 m²
Windows, south	-	6.0 m²

*Visiting scientist at SERI on leave from the Bulgarian Academy of Sciences until December 1, 1989.

TABLE 1.
Description of the Compared Design Strategies*

NO.	DESCRIPTION	SOUTH GLAZING, m^2
0	Base case	6.0
1	Suntempered	11.2
2	Suntempered, low-e glazing	11.2
3	Direct gain, double glazing	15.3
4	Direct gain, triple glazing or low-e glazing	15.3
5	Direct gain, R = 0.7 m2-K/W night insulation	15.3
6	Direct gain, R = 1.8 m2-K/W night insulation	15.3
7	Attached sunspace, 90/30 geometry	15.3
8	Attached sunspace, 90/30 (glazed end walls)	15.3
9	Semienclosed sunspace, vertical glazing only	15.3
10	Semienclosed sunspace, 50-degree sloped glazing	15.3
11	Trombe wall, black surface, single glazing	15.3
12	Trombe wall, selective surface, double glazing	15.3
13	Trombe wall, selective surface, single glazing	15.3
14	Water wall, selective surface, single glazing	15.3

*The sequential numbers in this table appear in Figures 2, 3, and 4 as indicators for the studied designs. All sunspace designs include double glazing.

The building envelope is normally made of bricks or reinforced concrete without insulation. It is reasonable to assume a thermal resistance of 1.1 m^2-K/W for the walls and 1.8 m^2-K/W for the roof. Double-glazed windows are available on all sides. A solar-savings fraction and annual heating estimate were first made for this house, which has no special passive solar features (the non-south glazing area is equal to 10% of the living area, and the south windows add another 5% and are designed primarily to satisfy general daylighting requirements).

The method used to estimate the energy saved per square meter of south glazing is the (monthly) Solar Load Ratio, which uses the variable-base degree days approach (Balcomb and Lekov, 1989). The house was assumed to be maintained at 18.3°C and to have an internal gain of 150 MJ/yr-m^2. Solar-savings fractions were determined from correlations based on the ratio of building net loss coefficient to net projected area. The correlations for the various passive systems used were developed from a large data base of hour-by-hour simulations.

PASSIVE SOLAR SYSTEMS COMPARED

The reference passive solar system designs are explained in detail in Balcomb et al. (1984). Several of them, most representative as design approaches for direct gain, sunspace, and thermal storage wall systems were chosen for this study. A comparison of the designs is listed in Table 1. See Balcomb et al. (1984) for specifics about the geometry, glazing, selective surfaces, and night insulation. The base-case house had 6 m^2 of south-facing glazing, and each compared passive solar system increased it to 15.3 m^2. A suntempering strategy, which increases the south-facing glazing to about 9% of the building's total living area without adding thermal mass (energy storage) beyond what is already available in the building structure, is also used (Balcomb and Lekov, 1989). In this case the suntempered design includes 11.2 m^2 for south glazing.

RESULTS

Figures 2, 3, and 4 present the energy performance of the passive solar designs studied for the three Bulgarian climatic zones. Each point on the graphs represents the percent solar savings (solar-savings fraction) and the appropriate yield. The value of the solar savings is a measure of how much an applied suntempered strategy (which increases the south glazing to 11.2 m^2) or added passive solar system (15.3 m^2) will reduce the house's need for purchased energy. The value of the yield is the annual net heating benefit of applying a suntempered or a passive solar strategy, measured in megajoules (MJ) saved per year per square meter of additional south glazing. Even the base case, which was a non-solar house (6 m^2 south glazing only), has some energy savings from solar irradiance. They are as follows for the studied locations:

Plovdiv - 4.3%
Michurin - 5.4%
Pleven - 3.2%.

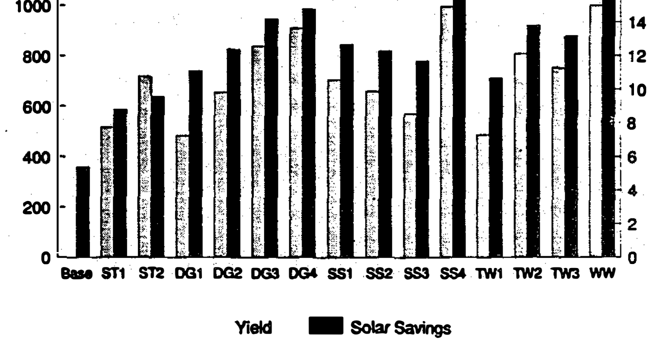

Figure 2. Performance potential of passive solar strategies in Michurin, Bulgaria.

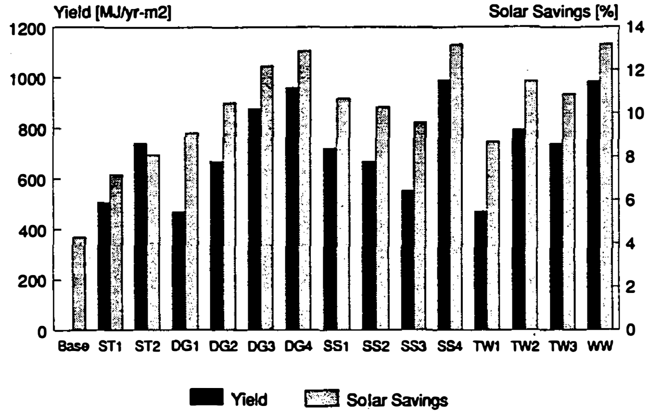

Figure 3. Performance potential of passive solar strategies in Plovdiv, Bulgaria.

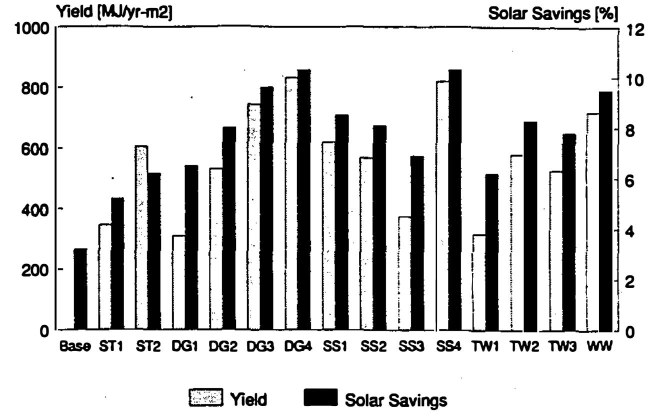

Figure 4. Performance potential of passive solar strategies in Pleven, Bulgaria.

The results showed that a design with a semienclosed sunspace and 50-degree sloped glazing contributes the best in all climatic areas. It contributes 820 MJ/yr-m^2 at the Pleven area and about 990 MJ/yr-m^2 at the Plovdiv and Michurin areas. The simplest direct-gain system, containing double glazing only, has the lowest energy contribution—310 MJ/yr-m^2 at Pleven and about 470 to 480 MJ/yr-m^2 at Plovdiv and Michurin. Black-surface, double-glazed massive walls in Plovdiv are less energy efficient (470 MJ/yr-m^2) than those having a selective surface (795 MJ/yr-m^2 with single glazing and 740 MJ/yr-m^2 with double glazing). The same ratio is valid for the other two climatic zones. Night insulation significantly improves energy-efficiencies of direct-gain systems. For Plovdiv, it increases from 670 MJ/yr-m^2 to 880 MJ/yr-m^2 and 960 MJ/yr-m^2 depending on the level of insulation. Water walls with selective surface and single glazing are among the most energy-efficient designs and contribute in the range of 720 MJ/yr-m^2 for the Pleven area to 1000 MJ/yr-m^2 for the Michurin area. Suntempered strategies (with about one-third less glazing area) at Plovdiv contribute 510 MJ/yr-m^2 for general double glazing and 740 MJ/yr-m^2 for low-e double glazing. The smaller glazing area explains the lower solar savings in the case of studied suntempered strategies.

CONCLUSIONS

This study shows that energy efficiency of residential houses and cottages in Bulgaria can be significantly improved by using passive solar systems in the design.

In all areas considered, any passive system contributes significantly to the energy savings. Although no clear winner appeared, the results showed that a design with a semienclosed sunspace and 50-degree sloped glazing contributes the best in all climatic areas, about twice that of the direct-gain system containing double glazing only. Using night insulation on direct-gain systems improves their overall energy efficiency by about 30%. In these climatic zones massive walls do not perform better than direct-gain and sunspace systems. Applying a selective surface on thermal storage walls improves energy performance in the range of 40% compared with a general black surface. Single glazing performs better than double glazing for this design. Water walls with selective surface and single glazing are among the most energy-efficient designs.

A suntempered strategy is an attractive option also. In these areas its energy contribution per m^2 (especially when low-e glazing is applied) is comparable to that of the passive systems. Significant energy savings can be achieved with much less glazing area. Of course, passive solar designs have some other advantages, such as the attractive living environments, good heat distribution, comfort, and a nice outside view, which are preferred by owners.

As a general conclusion, these strategies are about 15% less energy efficient at the Pleven area than in the climatic zones of the Plovdiv and Michurin areas.

For all strategies, the energy savings indicated assumed that general guidelines about energy-efficient design and construction were followed; the houses were properly sited and tightly built with high-quality windows and doors.

Although in practice many factors will affect actual energy performance, the information presented here will give architects and designers a general idea of how various systems will perform in these three Bulgarian climatic zones. This energy-performance information could be useful at the early design stage before extensive detail is available on the building form and specification or in cases when retrofit improvements are planned.

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